Functional diversity-area relationship in permanent grassland

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Abstract

The target of a multi-functional, sustainable use of grasslands requires deeper understanding of the relationships between grassland management and plant diversity and its consequences on ecosystem functioning. Some of these relationships are well known for specific pedo-climatic conditions. One option to extend our knowledge to a broader range of conditions is to aggregate different studies by performing a meta-analysis. Nevertheless, differences in sampling area between studies is a major challenge. For taxonomic diversity, species-area curves have been established for different habitats but references for functional diversity are scarce. We aimed at assessing the possibility of using functional diversity-area curves to correct for differing sampling area between studies before merging data for overall analysis on functional diversity. We measured diversity in 9 nested areas of increasing size (from 0.01 m² to 100 m²) in 16 grasslands with different management (grazing, mowing).We analyzed the effect of area on specific richness, functional richness, functional divergence and community weighed mean value of several functional traits (SLA, LDMC) and on the percentage of legumes. We conclude that correction for differing sampling area is possible for functional richness and community weighted mean values.

Keywords: plant functional traits, functional diversity, biodiversity-area relationships, survey minimal area.

Introduction

One argument for the preservation of permanent grassland in ruminant based farming systems is the provision of several ecosystem services. Ecosystem services (ES) are the services provided by the ecosystem for mankind. ES can be linked to some functional diversity criterion (de Bello et al., 2010). Functional diversity (FD) is the set of values of a functional trait (or multiple traits) of the individuals (or species) of a community. Functional diversity is driven by the environmental conditions (agricultural practices and pedoclimatic conditions). The relationships between FD and ES and between FD and environmental factors are generally studied only for local conditions. The generalization of these relationships has to be made at larger scales. One solution is to gather the different local studies. The main problem is the differences of survey protocol between studies, especially in term of the sampling area of the survey. Our goal is to assess the relationships between sampling area and some measures of functional diversity in order to correct for differing sampling area between studies.

Materials and Methods

We studied 16 permanent grasslands with contrasting management conditions in North-eastern part of France in 2010. The botanical composition was recorded on 9 different nested square areas (0.01 m², 0.0625 m², 0.25m², 0.5625m², 1m², 6.25m², 25m², 56.25m², 100m²). For quadrates below 1m², the abundances of species were visually estimated over the whole surface. For surfaces greater than 1m², the abundances were visually estimated by subsampling several quadrates of 0.25m². The number of quadrates was proportional to the surface (2 for 6.25 m², 4 for 25 m², 7 for 56.25 m², and 11 for the 100m²).Different plant diversity criterions were considered: the total number of species, the percentage of legumes in the sward, the aggregated Trait of Leaf Dry Matter Content (LDMC) and Specific Leaf Area (SLA). The aggregated trait is the sum of the trait of each species weighted by its relative abundance. It represented the average trait of the community. We also studied the functional amplitude of LDMC and SLA, as the difference between the minimum trait value and the maximum trait value of the community and the Rao index of these two traits. The values of the functional traits per species were taken from the LEDA trait database (Kleyer *et al*., 2008). These criteria were calculated using the FD package on R 2.13.1(Laliberté & Legendre 2010). The links between biodiversity criterion and the sampling area was studied using the model Criterion =a*log (area) +b. We calculated the area required to detect ± 5% of the diversity (minimal area) by linear interpolation between the measures. If the value of the diversity criteria was increasing with the sampling area, the minimal area was considered as the smallest area with 95% of the biodiversity of the 100 m² area. For diversity criteria values decreasing with the sampling area, the area with 105% of the biodiversity of the 100 m² area was considered minimal.

Results

We found a close relationship between the sampling area and the number of species, the functional amplitude of SLA and LDMC (Figure 1). For the other diversity criteria, no relationships with the area were found. The two aggregated traits have the smaller minimal area among all indexes (around 2 m²). The other indexes have a minimal area bigger than 10 m² (Table 1)

Table 1: Relationships between area and biodiversity (AT: aggregated trait, FA: functional amplitude, ns p-value no significant, * p-value significant)

Diversity criterion DC	Minimal area(m²)	Overall Model	R_2
Number of species	59.16	1.49 *log(Area)+15.35	0.35*
% legumes	54.90	-1.0*log(Area)+21.99	0.05 ns
Aggregated Trait of LDMC	1.61	0.23*log(Area)+ 214.87	0.003 ns
Aggregated Trait of SLA	2.09	-0.10*log(Area)+ 26.59	0.02 ns
FA LDMC	26.20	0.028*log(Area)+ 0.679	0.23*
FA SLA	14.25	0.015*log(Area)+ 0.694	0.11*
Rao LDMC	31.45	0.00*log(Area)+ 0.481	0.00ns
Rao SLA	55.72	0.015*log(Area)+ 0.694	0.00ns

Conclusion

Functional amplitude and the number of species can be related to the sampling area. A model of these relationships can be used to match data coming from various origins, differing in the sampling areas. For the aggregated traits, the minimal area is very small. All studies with a sampling area greater than 2 m² can be aggregated without correction. For the other indexes (Rao and % of legumes), the minimal area is large and no relationship with the sampling area was found. Thus harmonization for these indexes seems impossible. This preliminary work shows some ways to deal with difference in survey protocol for meta-analysis. However further studies with a larger number of grasslands in a wider range of conditions should be performed to ascertain these conclusions.

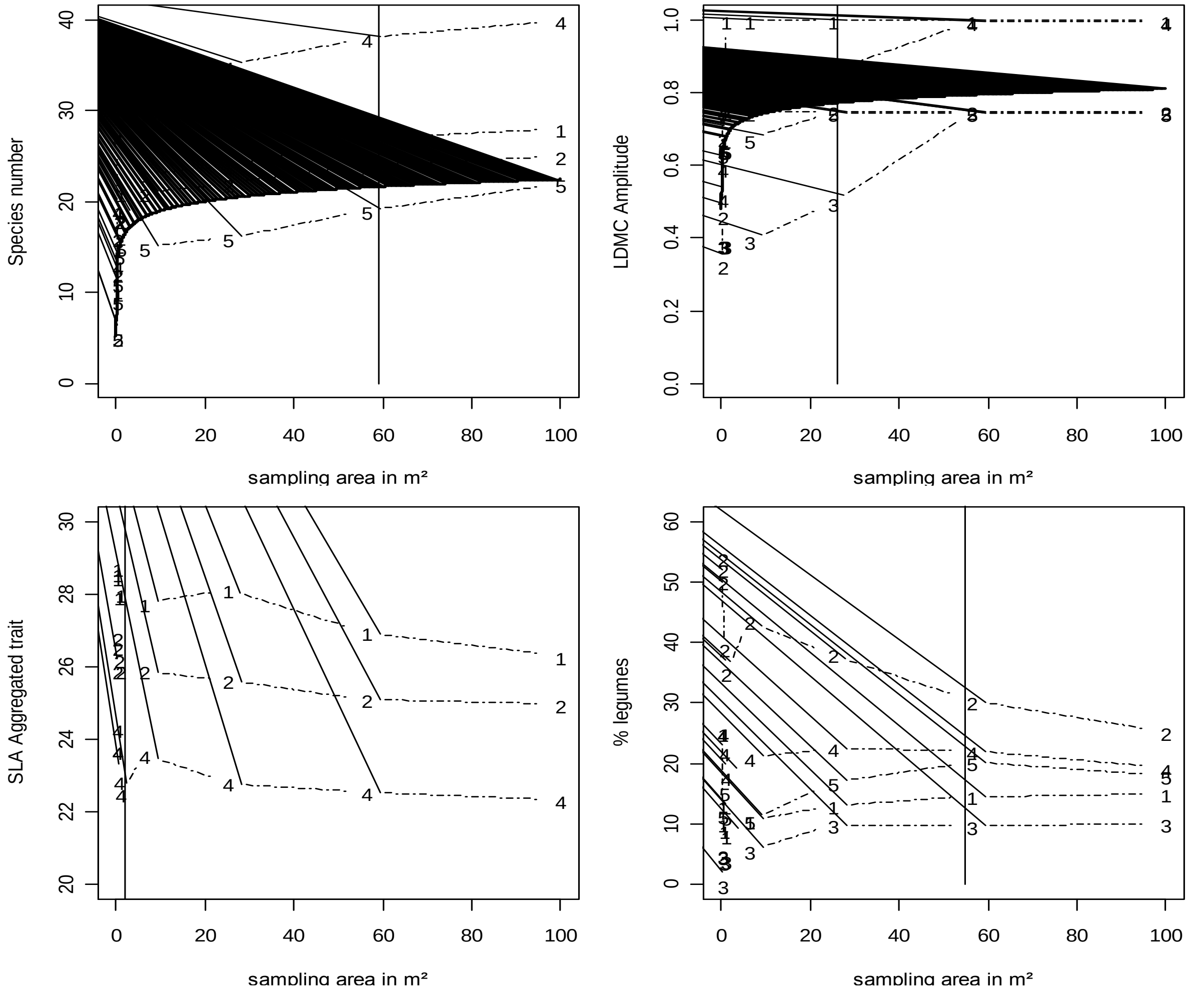

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Figure 1: Evolution of selected biodiversity criteria with sampling area for 5 grasslands. The vertical line represents the minimal area and the bold curve represents the overall model a) relationship with the number of species b) With the LDMC amplitude c) with the SLA Aggregated trait d) the percentage of legumes

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